TABLE 1. Mortality and Morbidity Risk Coefficients for Selected Radionuclides

Isotope	Lifetime Cancer Risk					
	Mortality			Morbidity		
	Inhalation	Ingestion	External	Inhalation	Ingestion	External
Americium-241	2.4×10^{-8}	9.5×10^{-11}	1.9×10^{-8}	2.8×10^{-8}	1.3×10^{-10}	2.8×10^{-8}
Americium-242m	2.7×10^{-8}	1.1×10^{-10}	-	3.0×10^{-8}	1.5×10^{-10}	-
Americium-243	2.3×10^{-8}	9.8×10^{-11}	4.3×10^{-7}	2.7×10^{-8}	1.4×10^{-10}	6.4×10^{-7}
Berkelium-247	4.0×10^{-8}	1.2×10^{-10}	2.1×10^{-7}	4.8×10^{-8}	1.6×10^{-10}	3.1×10^{-7}
Cadmium-109	2.0×10^{-11}	4.2×10^{-12}	-	2.2×10^{-11}	6.7×10^{-12}	-
Cadmium-113	8.1×10^{-11}	2.0×10^{-11}	-	1.1×10^{-10}	2.9×10^{-11}	-
Cadmium-113m	9.3×10^{-11}	2.5×10^{-11}	-	1.3×10^{-10}	3.6×10^{-11}	-
Californium-249	4.0×10^{-8}	1.2×10^{-10}	9.3×10^{-7}	4.8×10^{-8}	1.6×10^{-10}	1.4×10^{-6}
Californium-251	4.1×10^{-8}	1.3×10^{-10}	2.6×10^{-7}	4.9×10^{-8}	1.7×10^{-10}	3.8×10^{-7}
Carbon-14	6.5×10^{-12}	1.4×10^{-12}	-	7.1×10^{-12}	2.0×10^{-12}	-
Cesium-134	1.1×10^{-11}	3.5×10^{-11}	4.8×10^{-6}	1.6×10^{-11}	5.1×10^{-11}	7.1×10^{-6}
Cesium-135	1.3×10^{-12}	4.0×10^{-12}	-	1.9×10^{-12}	5.9×10^{-12}	-
Cesium-137	8.1×10^{-12}	2.5×10^{-11}	1.7×10^{-6}	1.2×10^{-11}	3.7×10^{-11}	2.5×10^{-6}
Chlorine-36	9.6×10^{-11}	2.9×10^{-12}	-	1.0×10^{-10}	4.4×10^{-12}	-
Cobalt-57	1.8×10^{-12}	9.0×10^{-13}	2.4×10^{-7}	2.1×10^{-12}	1.5×10^{-12}	3.6×10^{-7}
Cobalt-60	3.0×10^{-11}	1.4×10^{-11}	8.5×10^{-6}	3.6×10^{-11}	2.2×10^{-11}	1.2×10^{-5}
Curium-242	1.4×10^{-8}	3.2×10^{-11}	-	1.5×10^{-8}	5.5×10^{-11}	-
Curium-243	2.4×10^{-8}	8.5×10^{-11}	2.9×10^{-7}	2.7×10^{-8}	1.2×10^{-10}	4.2×10^{-7}
Curium-244	2.3×10^{-8}	7.5×10^{-11}	-	2.5×10^{-8}	1.1×10^{-10}	-
Curium-245	2.4×10^{-8}	9.5×10^{-11}	1.6×10^{-7}	2.8×10^{-8}	1.3×10^{-10}	2.4×10^{-7}
Curium-246	2.4×10^{-8}	9.3×10^{-11}	-	2.8×10^{-8}	1.3×10^{-10}	-
Curium-247	2.2×10^{-8}	9.0×10^{-11}	8.9×10^{-7}	2.5×10^{-8}	1.3×10^{-11}	1.3×10^{-6}
Curium-250	3.7×10^{-12}	3.6×10^{-12}	9.7×10^{-7}	4.5×10^{-12}	6.5×10^{-12}	1.4×10^{-6}
Europium-150	2.1×10^{-10}	3.6×10^{-12}	4.4×10^{-6}	2.6×10^{-10}	6.1×10^{-12}	6.5×10^{-6}
Europium-152	1.5×10^{-10}	5.0×10^{-12}	3.6×10^{-6}	1.9×10^{-10}	8.7×10^{-12}	5.3×10^{-6}
Europium-154	1.7×10^{-10}	8.5×10^{-12}	4.0×10^{-6}	2.1×10^{-10}	1.5×10^{-11}	5.8×10^{-6}
Europium-155	1.7×10^{-11}	1.6×10^{-12}	8.4×10^{-8}	1.9×10^{-11}	2.8×10^{-12}	1.2×10^{-7}
Iodine-129	6.2×10^{-12}	2.0×10^{-11}	-	6.1×10^{-11}	1.9×10^{-10}	-
Iodine-131	2.1×10^{-12}	6.9×10^{-12}	1.1×10^{-6}	1.9×10^{-11}	6.5×10^{-11}	1.6×10^{-6}
Neptunium-235	1.0×10^{-12}	2.8×10^{-13}	-	1.2×10^{-12}	5.1×10^{-13}	-
Neptunium-236	2.6×10^{-9}	1.5×10^{-11}	2.2×10^{-7}	3.0×10^{-9}	2.3×10^{-11}	3.2×10^{-7}
Neptunium-237	1.5×10^{-8}	5.8×10^{-11}	5.4×10^{-7}	1.8×10^{-8}	9.1×10^{-11}	8.0×10^{-7}
Nickel-59	3.6×10^{-13}	2.3×10^{-13}	-	4.7×10^{-13}	3.9×10^{-13}	-
Nickel-63	1.4×10^{-12}	5.7×10^{-13}	-	1.6×10^{-12}	9.5×10^{-13}	-
Plutonium-238	3.0×10^{-8}	1.3×10^{-10}	-	3.4×10^{-8}	1.7×10^{-10}	-
Plutonium-239	2.9×10^{-8}	1.3×10^{-10}	-	3.3×10^{-8}	1.7×10^{-10}	-
Plutonium-240	2.9×10^{-8}	1.3×10^{-10}	-	3.3×10^{-8}	1.7×10^{-10}	-
Plutonium-241	2.8×10^{-10}	1.9×10^{-12}	-	3.3×10^{-10}	2.3×10^{-12}	-
Plutonium-242	2.8×10^{-8}	1.3×10^{-10}	-	3.1×10^{-8}	1.7×10^{-10}	-
Potassium-40	2.1×10^{-10}	2.2×10^{-11}	5.5×10^{-7}	2.2×10^{-10}	3.4×10^{-11}	8.0×10^{-7}
Protactinium-231	2.5×10^{-7}	6.0×10^{-10}	1.1×10^{-6}	2.6×10^{-7}	8.8×10^{-10}	1.6×10^{-6}
Radium-226	2.4×10^{-8}	2.9×10^{-9}	5.8×10^{-6}	2.5×10^{-8}	4.0×10^{-9}	8.5×10^{-6}

Isotope	Lifetime Cancer Risk					
	Mortality			Morbidity		
	Inhalation	Ingestion	External	Inhalation	Ingestion	External
Radium-228	9.0×10^{-8}	1.3×10^{-9}	8.4×10^{-6}	9.7×10^{-8}	1.9×10^{-9}	1.2×10^{-5}
Samarium-146	1.2×10^{-8}	4.0×10^{-11}	-	1.4×10^{-8}	5.3×10^{-11}	-
Samarium-151	8.6×10^{-12}	4.6×10^{-13}	-	9.2×10^{-12}	8.1×10^{-13}	-
Selenium-79	2.3×10^{-12}	6.7×10^{-12}	-	3.3×10^{-12}	9.7×10^{-12}	-
Strontium-90	1.0×10^{-10}	7.5×10^{-11}	-	1.1×10^{-10}	9.5×10^{-11}	-
Technetium-97	7.6×10^{-13}	2.3×10^{-13}	-	8.5×10^{-13}	3.9×10^{-13}	-
Technetium-98	2.6×10^{-11}	6.0×10^{-12}	4.4×10^{-6}	3.0×10^{-11}	1.0×10^{-11}	6.5×10^{-6}
Technetium-99	1.3×10^{-11}	2.3×10^{-12}	-	1.4×10^{-11}	4.0×10^{-12}	-
Thorium-229	2.2×10^{-7}	4.7×10^{-10}	7.8×10^{-7}	2.3×10^{-7}	7.2×10^{-10}	1.2×10^{-6}
Thorium-230	2.7×10^{-8}	8.0×10^{-11}	-	2.9×10^{-8}	1.2×10^{-10}	-
Thorium-232	4.1×10^{-8}	9.1×10^{-11}	-	4.3×10^{-8}	1.3×10^{-10}	-
Tin-121m	4.1×10^{-11}	2.9×10^{-12}	-	4.4×10^{-11}	5.1×10^{-12}	-
Tin-126	3.9×10^{-10}	3.0×10^{-11}	8.8×10^{-6}	4.2×10^{-10}	5.3×10^{-11}	1.3×10^{-5}
Tritium (H-3)	3.9×10^{-14}	4.4×10^{-14}	-	5.6×10^{-14}	6.5×10^{-14}	-
Uranium-232	1.8×10^{-8}	2.7×10^{-10}	-	1.9×10^{-8}	3.9×10^{-10}	-
Uranium-233	1.1×10^{-8}	6.3×10^{-11}	-	1.2×10^{-8}	9.7×10^{-11}	-
Uranium-234	1.1×10^{-8}	6.1×10^{-11}	-	1.1×10^{-8}	9.5×10^{-11}	-
Uranium-235	9.5×10^{-9}	6.2×10^{-11}	3.7×10^{-7}	1.0×10^{-8}	9.8×10^{-11}	5.4×10^{-7}
Uranium-236	9.9×10^{-9}	5.8×10^{-11}	-	1.0×10^{-8}	9.0×10^{-11}	-
Uranium-238	8.8×10^{-9}	7.5×10^{-11}	-	9.3×10^{-9}	1.2×10^{-10}	-
Zirconium-93	8.4×10^{-12}	1.7×10^{-12}	-	9.2×10^{-12}	2.6×10^{-12}	-

This table provides selected risk coefficients for inhalation and dietary ingestion of various radionuclides, and for external gamma irradiation where that entry is appropriate. The mortality risk represents the lifetime risk of incurring a fatal cancer, and the morbidity risk represents the risk of incurring all cancers. Source: U.S. Environmental Protection Agency, *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, Federal Guidance Report 13, EPA 402-R-99-001, September 1999.

Values are averaged over all ages and both genders. (For context, 10^{-9} is a billionth, 10^{-12} is a trillionth, and a pCi is a picocurie, or a trillionth of a curie.) To convert to standard international units, multiply by 27 pCi per becquerel (Bq). Values presented here include the contributions from short-lived decay products, as indicated in the fact sheets. (For example, strontium-90 includes the contribution from yttrium-90, and uranium-238 includes the contribution from thorium-234).

For ingestion and inhalation, units are risk per pCi. For inhalation, the values corresponding to the recommended default absorption type for particulates are shown; the maximum value is given if no absorption type was recommended. For ingestion, the dietary values shown are the highest for ingestion exposures; values for tap water ingestion are typically 70 to 80% of those for diet. The values for tritium are for tritiated water. No values are available for curium-248 or curium-250; the values shown for curium-250 are those for its short-lived decay products.

For external exposure, risk coefficients are given for those radionuclides having gamma-ray energies in excess of 0.03 MeV per decay, accounting for the fraction of time that the radioactive decay results in the emission of gamma rays. A dash indicates the radionuclide or its decay products does not emit significant gamma radiation *(see the fact sheet for Radioactive Properties, Internal Distribution, and Risk Coefficients).* Units for external gamma risk coefficients shown in the table are risk per pCi/g soil for one year of exposure. Although no inhalation or ingestion coefficients are available for krypton isotopes, coefficients do exist for external gamma exposures. Submersion in a cloud of krypton gas poses the highest risk, and the following values are in units of risk per pCi/cm^3 air for one year of exposure. For krypton-81, mortality and morbidity risk coefficients are 1.5×10^{-5} and 2.3×10^{-5}, respectively. For krypton-85, mortality and morbidity risk coefficients are 8.5×10^{-6} and 1.2×10^{-5}, respectively.